Heights of rivers above zeros of gauges—Continued.

Stations.	Distance to mouth of river.	Danger-line on gauge.	Highest water.		Lowest water.		Mean stage.	Monthly range.
			Height.	Date.	Height.	Date.		
Mississippi River—Cont'd	*Miles.*	*Feet.*	*Feet.*		*Feet.*		*Feet.*	*Feet.*
Chester, Ill.	1,189	30	1.8	1	— 1.9	24, 25	—0.4	3.7
Cairo, Ill	1,073	40	19.3	28	6.9	7	10.7	12.4
Memphis, Tenn	843	33	12.2	31	3.2	1	5.5	9.0
Helena, Ark	767	44	16.4	31	3.3	1	6.7	13.1
Arkansas City, Ark.	635	42	14.6	31	1.5	1	5.5	13.1
Greenville, Miss	595	40	11.1	31	1.3	1	4.3	9.8
Vicksburg, Miss	474	41	7.9	31	— 0.8	2	3.7	8.7
New Orleans, La	108	16	4.1	13	2.3	5,6	3.1	1.8
Arkansas River.								
Wichita, Kans.	720	10	1.7	14	0.8	1-12, 29, 30	1.1	0.9
Fort Smith, Ark.	345	22	2.5	18	0.6	7-9	1.4	1.9
Dardanelle, Ark.	250	21	2.6	19	— 0.6	1,5-12	0.6	3.2
Little Rock, Ark.	170	23	4.9	22	1.2	1-9	2.5	3.7
White River.								
Newport, Ark	150	26	4.7	24	0.4	1-3	2.0	4.3
Des Moines River.								
Des Moines, Iowa †	150	19	.....	.....	.....	.....	.....	.....
Illinois River.								
Peoria, Ill.	135	14	4.5	1	4.1	27-31	4.2	0.4
Missouri River.								
Bismarck, N. Dak.	1,201	14	4.6	29	2.7	12, 13	3.5	1.9
Pierre, S. Dak. †	1,006	14	.....	.....	.....	.....	.....	.....
Sioux City, Iowa †	676	19	.....	.....	.....	.....	.....	.....
Omaha, Nebr. †	561	18	.....	.....	.....	.....	.....	.....
St. Joseph, Mo.	373	10	0.7	24-26	— 2.7	6-8	—0.9	3.4
Kansas City, Mo. [a]	280	21	5.2	30	2.0	7,8	3.5	3.2
Boonville, Mo.	191	20	4.5	1	0.9	20	2.6	3.6
Hermann, Mo.	95	21	— 0.7	1	— 3.6	22	—2.3	2.9
Ohio River.								
Pittsburg, Pa	966	22	13.7	17	3.4	31	7.2	10.3
Davis Island Dam, Pa.	960	25	13.7	17	5.5	5,31	8.5	8.2
Wheeling, W. Va.	875	36	18.9	17	6.2	6	10.6	12.7
Parkersburg, W. Va.	785	35	18.0	19	7.7	29,30	11.6	10.3
Point Pleasant, W. Va.	703	36	19.1	22	6.6	31	12.2	12.5
Catlettsburg, Ky	651	50	22.8	23	9.0	31	15.0	13.8
Portsmouth, Ohio	612	50	23.2	23	10.2	31	15.7	13.0
Cincinnati, Ohio	499	45	25.5	22	12.0	1	17.8	13.5
Louisville, Ky.	367	24	10.1	23	6.0	1	8.0	4.1
Evansville, Ind	184	30	18.9	26	7.8	4	12.5	11.1
Paducah, Ky.	47	40	18.0	27	4.8	6	9.5	13.2
Alleghany River.								
Warren, Pa	177	7	5.4	16	1.2	5	2.7	4.2
Oil City, Pa	123	13	7.0	16	2.2	4,5	3.5	4.8
Parkers Landing, Pa.	73	20	8.0	16	1.7	31	3.7	6.3
Freeport, Pa.	26	20	13.1	16	3.8	31	6.9	9.3
Conemaugh River.								
Johnstown, Pa.	64	7	3.9	16	1.7	28, 29	2.5	2.2
Red Bank Creek.								
Brookville, Pa.	35	8	2.5	12	1.0	2-4, 29, 31	1.7	1.5
Beaver River.								
Ellwood Junction, Pa.	10	14	3.6	16	0.1	7-10	1.1	3.5
Cumberland River.								
Burnside, Ky	434	50	11.8	22	0.2	1,2	2.7	11.6
Carthage, Tenn.	257	30	12.8	24	0.8	2	4.3	12.0
Nashville, Tenn	175	40	16.4	24	1.3	1	6.6	15.1
Great Kanawha River.								
Charleston, W. Va.	61	30	8.0	22	3.7	29, 30	6.3	4.3
New River.								
Hinton, W. Va.	95	14	3.0	23	1.2	14	1.8	1.8
Licking River.								
Falmouth, Ky.	30	25	6.5	21	1.8	13, 14	2.9	4.7
Miami River.								
Dayton, Ohio	69	18	3.4	18	1.1	29	1.9	2.3
Monongahela River.								
Weston, W. Va.	161	18	9.6	5	— 1.0	10, 11	1.2	10.6
Fairmont, W. Va.	119	25	10.5	6	1.1	3,4	3.7	9.4
Greensboro, Pa.	81	18	17.0	5	7.7	3, 4, 13, 14	9.8	9.3
Lock No. 4, Pa.	40	28	20.6	6	7.2	4	10.6	13.4
Cheat River.								
Rowlesburg, W. Va.	36	14	9.0	5	2.5	2,3	4.1	6.5
Youghiogheny River.								
Confluence, Pa.	59	10	5.6	5	1.8	3	3.3	3.8
West Newton, Pa.	15	23	6.5	6	0.8	4	2.4	5.7
Muskingum River.								
Zanesville, Ohio	70	20	9.6	17	6.8	4, 10, 11	7.8	2.8
Tennessee River.								
Knoxville, Tenn.	614	29	3.5	23, 24	0.5	2,3	1.7	3.0
Kingston, Tenn	534	25	5.0	22	0.0	1-3	1.3	5.0
Chattanooga, Tenn	430	33	10.2	23	1.0	1	3.8	9.2
Bridgeport, Ala	390	24	8.2	24	0.0	1	2.4	8.2
Florence, Ala.	220	16	8.7	25	— 0.2	1,2	2.9	8.9
Johnsonville, Tenn.	94	21	13.3	25, 26	0.0	1,2	5.2	13.3

Heights of rivers above zeros of gauges—Continued.

Stations.	Distance to mouth of river.	Danger line on gauge.	Highest water.		Lowest water.		Mean stage.	Monthly range.
			Height.	Date.	Height.	Date.		
Clinch River.	*Miles.*	*Feet.*	*Feet.*		*Feet.*		*Feet.*	*Feet.*
Speers Ferry, Va.	156	20	1.5	23	— 0.7	1	0.1	2.2
Clinton, Tenn	46	25	7.0	23	2.0	1,2	3.9	5.0
Wabash River.								
Mount Carmel, Ill	50	15	7.4	20, 21	2.2	11	4.1	5.2
Red River.								
Arthur City, Tex.	688	27	3.6	20	2.1	1-3, 14-18	2.5	1.5
Fulton, Ark	565	28	4.6	31	1.0	1-10	2.1	3.6
Shreveport, La.	449	29	1.8	31	— 2.1	5-10	—1.1	3.9
Alexandria, La	139	33	6.3	27	— 2.8	1,2	1.7	9.1
Atchafalaya Bayou.								
Melville, La.	100*	31	14.4	27	2.3	1	9.2	12.1
Ouachita River.								
Camden, Ark.	340	39	15.0	24	3.5	1-3	6.6	11.5
Monroe, La	100	40	16.6	30	0.5	1,2	6.2	16.1
Yazoo River.								
Yazoo City, Miss.	80	25	11.5	27	— 2.1	1,2	5.9	13.6
Chattahoochee River.								
Columbus, Ga.	140	20	2.6	15	1.3	22, 24	1.8	1.3
Flint River.								
Albany, Ga.	80	20	3.2		1.1	1	2.1	2.1
Cape Fear River.								
Fayetteville, N. C.	100	38	10.0	28	3.0	14	5.1	7.0
Columbia River.								
Umatilla, Oreg	270	25	5.8	12-14	4.0	24, 25	5.0	1.8
The Dalles, Oreg.	166	40	10.0	14	5.9	26	7.9	4.1
Willamette River.								
Albany, Oreg	99	20	17.5	16	6.0	24, 25	10.4	11.5
Portland, Oreg	10	15	15.1	14, 15	6.0	23, 24	10.2	9.1
Edisto River.								
Edisto, S. C	75	6	3.8	31	2.3	16	2.8	1.5
James River.								
Lynchburg, Va.	257	18	1.7	16	— 0.1	1,2	0.7	1.8
Richmond, Va.	110	12	1.5	16	— 0.1	2-4	0.3	1.6
Alabama River.								
Montgomery, Ala.	265	35	5.3	25	— 0.7	2	2.2	6.0
Selma, Ala.	212	35	6.0	28	— 1.6	1	2.3	7.6
Coosa River.								
Gadsden, Ala [d]	144	18	6.3	24	— 0.2	1	2.2	6.5
Tombigbee River.								
Columbus, Miss.	285	33	11.5	23	— 3.6	1	5.0	15.1
Demopolis, Ala.	155	35	27.4	27	— 2.1	1,2	11.4	29.5
Black Warrior River.								
Tuscaloosa, Ala.	90	38	31.0	23	— 1.3	1	8.8	32.3
Pedee River.								
Cheraw, S. C.	145	27	4.5	28, 29	1.1	14	2.4	3.4
Black River.								
Kingstree, S. C.	60	12	5.3	31	2.4	6-10	3.4	2.9
Lumber River.								
Fairbluff, N. C.	10	6	1.7	31	0.2	1	0.7	1.5
Lynch Creek.								
Effingham, S. C.	35	12	5.7	28	3.3	1	4.0	2.4
Potomac River.								
Harpers Ferry, W. Va.	170	16	5.3	16	1.3	4	2.5	4.0
Roanoke River.								
Clarksville, Va.	155	12	0.4	23	0.1	3-21, 27-31	0.1	0.3
Sacramento River.								
Redbluff, Cal.	241	23	7.2	8	0.4	1,2	2.3	6.8
Sacramento, Cal.	70	25	14.9	13	9.7	6,7	11.7	5.2
Santee River.								
St. Stephens, S. C.	50	12	6.1	3	1.4	17	3.2	4.7
Congaree River.								
Columbia, S. C.	37	15	2.2	23	1.2	31	1.6	1.0
Wateree River.								
Camden, S. C.	45	24	6.0	28	3.0	13	4.1	3.0
Savannah River.								
Augusta, Ga.	130	32	7.9	1	5.9	13	6.9	2.0
Susquehanna River.								
Wilkesbarre, Pa.	178	14	9.0	17, 18	3.0	{2-6, 11-13, 24-31}	4.5	6.0
Harrisburg, Pa.	70	17	8.2	18	2.5	31	4.6	5.7
Juniata River.								
Huntingdon, Pa.	80	24	6.0	15	3.5	2-4	4.0	2.5
W. Br. of Susquehanna.								
Williamsport, Pa.	35	20	7.7	17	2.0	30	4.3	5.7
Waccamaw River.								
Conway, S. C.	40	7	2.2	3	0.4	12, 13, 18	1.0	1.8

* Distance to Gulf of Mexico. † Frozen. [a] Frozen, 21-31. [b] Frozen, 23-31. [c] Frozen, 5, 6, 20-25. [d] No observations, 17, 18.

SPECIAL CONTRIBUTIONS.

A PRELIMINARY DISCUSSION OF CERTAIN CYCLICAL CHANGES IN INDIA.

By W. L. DALLAS, Simla, India (dated December 8, 1897).

In the Indian Meteorological Memoirs, Vol. VI, it was shown by the author, and in a later volume of the same memoirs, by Mr. E. Douglas Archibald, that the effect on the course of barometric pressure of the periodic changes in the number of solar spots is to occasion a real variation in pressure of sufficient magnitude to enter into the discussion of the secular variations of weather. Having reached this conclusion, and it being evident both from present watching as well as from past records of weather, that the sun-spot influence alone was insufficient to account for the weather variations which are on record, it appeared to the writer desirable to carry the investigation a step further, and by eliminating the solar-spot influence to see whether there would then ap-

pear in the pressure curve other secular changes which would still further explain the recorded variations in the amount of rainfall, etc., in India.

The only places in India for which long series of pressure observations exist are the presidency towns of Bombay, Madras, and Calcutta. The annual mean pressure observations for these three centers are given below, together with each year's variation from the average of the whole:

TABLE I.—*Annual mean barometric pressure and variations from normal.*

Year.	Madras.		Bombay.		Calcutta.	
	Pressure.	Variation.	Pressure.	Variation.	Pressure.	Variation.
	Inches.	*Inch.*	*Inches.*	*Inch.*	*Inches.*	*Inch.*
1841	29.835	−.008	.....	.....	.....	.....
1842	.826	−.007	.....	.....	.....	.....
1843	.846	+.003	.....	.....	.....	.....
1844	.839	−.004	.....	.....	.....	.....
1845	.853	+.010	.....	.....	.....	.....
1846	.856	+.013	29.809	−.008	.....	.....
1847	.834	−.009	.797	−.015	.....	.....
1848	.835	−.008	.805	−.007	.....	.....
1849	.819	−.024	.798	−.014	.....	.....
1850	.835	−.008	.808	−.004	.....	.....
1851	.835	−.008	.796	−.016	.....	.....
1852	.847	+.004	.805	−.007	.....	.....
1853	.848	+.005	.814	+.002	29.771	−.013
1854	.844	+.001	.804	−.008	.781	−.003
1855	.862	+.019	.824	+.012	.788	+.004
1856	.849	+.006	.806	−.006	.779	−.005
1857	.852	+.009	.808	−.004	.770	−.014
1858	.858	+.015	.812	.000	.781	−.003
1859	.850	+.007	.812	.000	.792	+.008
1860	.835	−.008	.804	−.008	.764	−.020
1861	.839	−.014	.797	−.015	.761	−.023
1862	.839	−.014	.793	−.029	.767	−.017
1863	.832	−.011	.792	−.020	.760	−.024
1864	.874	+.031	.832	+.020	.795	+.011
1865	.865	+.022	.811	−.001	.802	+.018
1866	.845	+.002	.822	+.010	.788	+.004
1867	.855	+.012	.824	+.012	.805	+.021
1868	.853	+.010	.836	+.024	.805	+.021
1869	.824	−.019	.814	+.002	.790	+.006
1870	.814	−.029	.797	−.015	.773	−.011
1871	.836	−.007	.805	−.007	.776	−.008
1872	.826	−.017	.795	−.017	.787	+.003
1873	.839	−.004	.811	−.001	.776	−.008
1874	.836	−.007	.810	−.002	.789	+.005
1875	.835	−.008	.808	−.004	.776	−.008
1876	.835	−.008	.816	+.004	.775	−.009
1877	.889	+.046	.846	+.034	.828	+.044
1878	.848	+.005	.800	−.012	.804	+.020
1879	.829	−.014	.801	−.011	.777	−.007
1880	.839	−.004	.818	+.006	.790	+.006
1881	.846	+.003	.820	+.008	.791	+.007
1882	.831	−.012	.807	−.005	.776	−.008
1883	.841	−.002	.812	.000	.774	−.010
1884	.863	+.020	.827	+.015	.792	+.008
1885	.864	+.021	.826	+.014	.800	+.016
1886	.838	−.005	.809	−.003	.790	+.006
1887	.834	−.009	.818	+.006	.781	−.003
1888	.858	+.015	.832	+.020	.785	+.001
1889	.840	−.008	.818	+.006	.784	.000
1890	.837	−.006	.814	+.002	.776	−.008
1891	.856	+.013	.834	+.022	.794	+.010
1892	.825	−.018	.790	−.022	.768	−.016
1893	.840	−.003	.815	+.003	.794	+.010
1894	.833	−.010	.809	−.003	.773	−.011
1895	.847	+.004	.819	+.007	.789	+.005
1896	.851	+.008	.819	+.007	.771	−.013
Mean	29.843	.....	29.812	.....	29.784	.....

In order to ascertain what portion of each of these variations was attributable to the variations in the number of the solar spots the following table was constructed, giving the annual variations in 11-year series for Madras, Calcutta, and Bombay, respectively.

TABLE II.—*Annual variations arranged in* 11-*year series.*

MADRAS.

Year.	Variation.	Year.	Variation.	Year.	Variation.	Year.	Variation.	Year.	Variation.	Year.	Variation.	Mean variation.
	Inch.		*Inch.*		*Inch.*		*Inch.*		*Inch.*		*Inch.*	*Inch.*
1841	−.008	1852	+.004	1863	−.011	1874	−.007	1885	+.021	1896	+.008	+.0012
1842	−.007	1853	+.005	1864	+.031	1875	−.008	1886	−.005	.....	.....	+.0032
1843	+.003	1854	+.001	1865	+.022	1876	−.008	1887	−.009	.....	.....	+.0018
1844	−.004	1855	+.019	1866	+.002	1877	+.046	1888	+.015	.....	.....	+.0156
1845	+.010	1856	+.006	1867	+.012	1878	+.005	1889	−.008	.....	.....	+.0060
1846	+.013	1857	+.009	1868	+.010	1879	−.014	1890	−.006	.....	.....	+.0024
1847	−.009	1858	+.015	1869	−.019	1880	−.004	1891	+.013	.....	.....	−.0008

TABLE II.—*Annual variations arranged in* 11-*year series*—Continued.

MADRAS—*Continued.*

Year.	Variation.	Year.	Variation.	Year.	Variation.	Year.	Variation.	Year.	Variation.	Year.	Variation.	Mean variation.
	Inch.		*Inch.*		*Inch.*		*Inch.*		*Inch.*		*Inch.*	*Inch.*
1848	−.008	1859	+.007	1870	−.029	1881	+.003	1892	−.018	.....	.....	−.0090
1849	−.024	1860	−.008	1871	−.007	1882	−.012	1893	−.008	.....	.....	−.0108
1850	−.008	1861	−.014	1872	−.017	1883	−.002	1894	−.010	.....	.....	−.0102
1851	−.008	1862	−.014	1873	−.004	1884	+.020	1895	+.004	.....	.....	−.0004

CALCUTTA.

.....	.....	.....	.....	1863	−.024	1874	+.005	1885	+.016	1896	−.013	−.0040
.....	.....	1853	−.018	1864	+.011	1875	−.008	1886	+.006	.....	.....	−.0010
.....	.....	1854	−.008	1865	+.018	1876	−.009	1887	−.008	.....	.....	+.0007
.....	.....	1855	+.004	1866	+.004	1877	+.044	1888	+.001	.....	.....	+.0132
.....	.....	1856	−.005	1867	+.021	1878	+.020	1889	.000	.....	.....	+.0090
.....	.....	1857	−.014	1868	+.021	1879	−.007	1890	−.008	.....	.....	−.0020
.....	.....	1858	−.008	1869	+.006	1880	+.006	1891	+.010	.....	.....	+.0047
.....	.....	1859	+.008	1870	−.011	1881	+.007	1892	−.016	.....	.....	−.0080
.....	.....	1860	−.020	1871	−.008	1882	−.008	1893	+.010	.....	.....	−.0065
.....	.....	1861	−.023	1872	+.003	1883	−.010	1894	−.011	.....	.....	−.0102
.....	.....	1862	−.017	1873	−.008	1884	+.008	1895	+.005	.....	.....	−.0080

BOMBAY.

.....	.....	1852	−.007	1863	−.020	1874	−.002	1885	+.014	1896	+.007	−.0016
.....	.....	1853	+.002	1864	+.020	1875	−.004	1886	−.003	.....	.....	+.0088
.....	.....	1854	−.008	1865	−.001	1876	+.004	1887	+.006	.....	.....	+.0002
.....	.....	1855	+.012	1866	+.010	1877	+.034	1888	+.020	.....	.....	+.0190
.....	.....	1856	−.006	1867	+.012	1878	−.012	1889	+.006	.....	.....	.0000
1846	−.003	1857	−.004	1868	+.024	1879	−.011	1890	+.002	.....	.....	+.0016
1847	−.015	1858	.000	1869	+.002	1880	+.006	1891	+.022	.....	.....	+.0080
1848	−.007	1859	.000	1870	−.015	1881	+.008	1892	−.022	.....	.....	−.0072
1849	−.014	1860	−.008	1871	−.007	1882	−.005	1893	+.003	.....	.....	−.0062
1850	−.004	1861	−.015	1872	−.017	1883	.000	1894	−.008	.....	.....	−.0078
1851	−.016	1862	−.029	1873	−.001	1884	+.015	1895	+.007	.....	.....	−.0048

The variations differ somewhat for the three different stations, the curve for Calcutta being less distinct and less regular than those for Madras and Bombay. It may be mentioned here that for each of the three stations the pressure variations were also determined corresponding with the exact number of the sun spots for each year, using both the maximum and the minimum years as the bases, but it was found in the end that the most regular and symmetrical returns were obtained from the simple 11-year cycle.

Table III gives the pressure variations for the 11-year periods for the three stations combined, and, by changing the signs of the variations, as is shown in the last column of the table, these departures become changed into the corrections which it is necessary to apply to each year of the different series in order to eliminate the sun-spot effect from the curve of pressure.

TABLE III.

Series of years.	Mean variation of pressure.			Mean of three.	Mean correction.
	Madras.	Bombay.	Calcutta.		
	Inch.	*Inch.*	*Inch.*	*Inch.*	*Inch.*
1841-52-63-74-85-96	+.0012	−.0016	−.0040	−.0015	+.002
1842-53-64-75-86	+.0032	+.0088	−.0010	+.0020	−.002
1843-54-65-76-87	+.0018	+.0002	+.0007	+.0009	−.001
1844-55-66-77-88	+.0156	+.0190	+.0132	+.0159	−.016
1845-56-67-78-89	+.0060	.0000	+.0090	+.0050	−.005
1846-57-68-79-90	+.0024	+.0016	−.0020	+.0007	−.001
1847-58-69-80-91	−.0008	+.0030	+.0047	+.0023	−.002
1848-59-70-81-92	−.0090	−.0072	−.0030	−.0064	+.006
1849-60-71-82-93	−.0108	−.0062	−.0065	−.0078	+.008
1850-61-72-83-94	−.0102	−.0078	−.0102	−.0094	+.009
1851-62-73-84-95	−.0004	−.0048	−.0030	−.0027	+.003

Table IV gives the actual annual pressure for each year for the three stations combined, and also the annual pressure when the corrections for the solar-spot cycle, as given in the last column of Table III, have been applied.

TABLE IV.—*Mean pressure of the three stations, Madras, Bombay, and Calcutta, and, also, as corrected for the* 11-*year cycle.*

Year.	Mean pressure.	Mean pressure corrected.	Year.	Mean pressure.	Mean pressure corrected.	Year.	Mean pressure.	Mean pressure corrected.
	Inches.	*Inches.*		*Inches.*	*Inches.*		*Inches.*	*Inches.*
1841	29.835*	29.807	1860	29.801	29.809	1879	29.802	29.801
1842	.836*	.804	1861	.796	.805	1880	.816	.814
1843	.846*	.815	1862	.798	.796	1881	.819	.825
1844	.839*	.798	1863	.795	.797	1882	.805	.813
1845	.853*	.818	1864	.834	.832	1883	.809	.818
1846	.835†	.817	1865	.826	.825	1884	.827	.830
1847	.816†	.799	1866	.818	.802	1885	.830	.832
1848	.820†	.811	1867	.828	.823	1886	.812	.810
1849	.809†	.802	1868	.831	.830	1887	.811	.810
1850	.822†	.816	1869	.809	.807	1888	.825	.809
1851	.816†	.804	1870	.795	.801	1889	.814	.809
1852	.826†	.813	1871	.806	.814	1890	.809	.808
1853	.811	.809	1872	.803	.812	1891	.828	.826
1854	.810	.809	1873	.809	.812	1892	.794	.800
1855	.825	.809	1874	.812	.814	1893	.816	.824
1856	.811	.806	1875	.806	.804	1894	.805	.814
1857	.810	.809	1876	.809	.808	1895	.818	.821
1858	.817	.815	1877	.854	.838	1896	.814	.816
1859	.818	.824	1878	.817	.812			

*Means of Madras only. †Means of Madras and Bombay only.

Since the annual mean pressure of the whole series is (see Table I) for—

Madras, 29.843 (a);
Bombay, 29.812 (b);
Calcutta, 29.784 (c);

and since $\frac{a+b+c}{3} = 29.813$ (d);

therefore, (a) alone is 0.030″ higher than (d) and $\frac{a+b}{2}$ is 0.015″ higher than (d).

Thus, the Madras means for each year 1841 to 1845 require a correction of —0.030″ to reduce each to the equivalent mean of the three stations, and the combined means of Madras and Bombay for each of the years 1846 to 1852 require a correction of —0.015″. These corrections have been combined with the sun-spot correction in obtaining the third column of Table IV, and the following diagram shows these figures graphically:

FIG. 1.—Indian pressure curve, corrected for sun-spot variation as derived from 11-year period.

The curve, thus corrected, shows a complicated course, and is obviously composed of numerous small oscillations. At this stage of the investigation it was suggested to me by Mr. Eliot that it would be interesting to treat the Mauritius pressure curve in the same manner. Therefore, the annual pressures for Mauritius were corrected for the 11-year cycle, and the results obtained are shown graphically in the accompanying diagram:

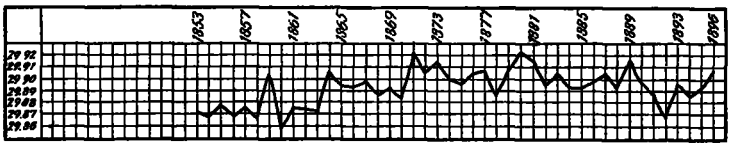

FIG. 2.—Mauritius pressure curve, corrected for sun-spot variation as derived from 11-year period.

For the period 1853 to 1870 there is no information as to the data from which the means for Mauritius were derived, but from 1871 onward the hours of observation are given, and it is thus possible to obtain correct values of barometric pressure. It is obvious that the figures of the earlier years of the series are not comparable with those after 1870, but the latter were sufficient to show that there existed a 9-year period in the pressure variations at Mauritius, and this gave a clew to what appears to be a similar manifestation in the records of mean pressure over India; the course of the Indian pressure curve is, however, generally the reverse of that prevailing at Mauritius. A careful inspection of the Indian curve shows that the crests of the 9-year cycle occur in the years 1841, 1850, 1859, 1868, 1877, 1886, and 1895, and starting with these years the following table has been constructed.

TABLE V.—*Indian pressures arranged in* 9-*year cycles.*

Year.	Variation.	Year.	Variation.	Year.	Variation.	Year.	Variation.	Year.	Variation.	Year.	Variation.	Year.	Variation.	Mean.	
														Variation.	Correction.
	Inch.		*Inch.*		*Inch.*		*Inch.*		*Inch.*		*Inch.*		*Inch.*	*Inch.*	*Inch.*
1841	—.006	1850	+.008	1859	+.011	1868	+.017	1877	+.025	1886	—.008	1895	+.008	+.008	—.008
1842	—.009	1851	—.009	1860	—.004	1869	—.006	1878	—.001	1887	—.008	1896	+.003	—.004	+.004
1843	+.002	1852	.000	1861	—.008	1870	—.012	1879	—.012	1888	—.004	....	.....	—.006	+.006
1844	—.020	1853	—.004	1862	—.017	1871	+.001	1880	+.001	1889	—.004	....	.....	—.007	+.007
1845	+.005	1854	—.004	1863	—.016	1872	—.001	1881	+.012	1890	—.005	....	.....	—.002	+.002
1846	+.004	1855	—.004	1864	+.019	1873	—.001	1882	.000	1891	+.013	..	.....	+.005	—.005
1847	—.014	1856	—.007	1865	+.012	1874	+.001	1883	+.005	1892	—.013	....	.....	—.003	+.003
1848	—.002	1857	—.004	1866	—.011	1875	—.009	1884	+.017	1893	+.010	....	.....	.000	.000
1849	—.011	1858	+.002	1867	+.010	1876	—.005	1885	+.019	1894	+.001	...	.....	+.003	—.003

The mean values in the last column of Table V show a maximum pressure variation in the 1841 series, or the first year of the 9-year cycle; a fall to a minimum in the fourth year of the cycle; then a rise to the sixth year, when marked irregularity occurs; a fall in the seventh year; and, finally, a rise again to the maximum in the first year. Reversing the signs of the variations a correction is obtained which, applied to the different years, removes this cycle from the pressure records. The following table, VI, shows (1) the crude barometric annual averages for the three stations combined and the variation of each annual average from the normal; (2) the mean annual pressure of the three stations combined after being corrected for the influence of the 11-year cycle; (3) the variation of each year from the new normal; (4) the mean annual pressure of the three stations combined after being corrected both for the 11-year and for the 9-year cycles; (5) the variation of each year from the last normal.

TABLE VI.—*Indian pressures corrected for cyclical variations.*

Year.	Crude means.	Variation.	Means corrected for 11-year cycle.	Variation.	Means corrected for 11 and 9 year cycles.	Variation.
	Inches.	*Inch.*	*Inches.*	*Inch.*	*Inches.*	*Inch.*
1841	29.805	—.007	29.807	—.006	29.799	—.014
1842	.806	—.006	.804	—.009	.808	—.005
1843	.816	+.004	.815	+.002	.821	+.008
1844	.809	—.003	.793	—.020	.800	—.013
1845	.823	+.011	.818	+.005	.820	+.006
1846	.818	+.006	.817	+.004	.812	—.001
1847	.801	—.011	.799	—.014	.802	—.011
1848	.805	—.007	.811	—.002	.811	—.002
1849	.794	—.018	.802	—.009	.799	—.014
1850	.807	—.005	.816	+.003	.808	—.005
1851	.801	—.011	.804	—.009	.808	—.005
1852	.811	—.001	.813	.000	.819	+.006
1853	.811	—.001	.809	—.004	.816	+.003
1854	.810	—.002	.809	—.004	.811	—.002
1855	.825	+.013	.809	—.004	.804	—.009
1856	.811	—.001	.806	—.007	.809	—.004
1857	.810	—.002	.809	—.004	.809	—.004
1858	.817	+.005	.815	+.002	.812	—.001
1859	.818	+.006	.824	+.009	.816	+.003
1860	.801	—.011	.809	—.004	.813	.000
1861	.796	—.016	.805	—.008	.811	—.002
1862	.793	—.019	.796	—.017	.803	—.010
1863	.795	—.017	.797	—.016	.799	—.014
1864	.834	+.022	.832	+.019	.827	+.014
1865	.826	+.014	.825	+.012	.828	+.015
1866	.818	+.006	.802	—.011	.802	—.011
1867	.828	+.016	.823	+.010	.820	+.007
1868	.831	+.019	.830	+.017	.822	+.009
1869	.809	—.003	.807	—.006	.811	—.002
1870	.795	—.017	.801	—.012	.807	—.006
1871	.806	—.006	.814	+.001	.821	+.008
1872	.803	—.009	.812	—.001	.814	+.001

TABLE VI.—*Indian pressures corrected for cyclical variations*—Continued.

Year.	Crude means.	Variation.	Means corrected for 11-year cycle.	Variation.	Means corrected for 11 and 9 year cycles.	Variation.
	Inches	*Inch.*	*Inches.*	*Inch.*	*Inches.*	*Inch.*
1873	29.809	−.003	29.812	−.001	29.807	−.006
1874	.812	.000	.814	+.001	.817	+.004
1875	.806	−.006	.804	−.009	.804	−.009
1876	.809	−.003	.808	−.005	.805	−.008
1877	.854	+.042	.838	+.025	.830	+.017
1878	.817	+.005	.812	−.001	.816	+.003
1879	.802	−.010	.801	−.012	.807	−.006
1880	.816	+.004	.814	+.001	.821	+.008
1881	.819	+.007	.825	+.012	.827	+.014
1882	.805	−.007	.813	.000	.808	−.005
1883	.809	−.003	.818	+.005	.821	+.008
1884	.827	+.015	.830	+.017	.830	+.017
1885	.830	+.018	.832	+.019	.829	+.016
1886	.812	.000	.810	−.003	.802	−.011
1887	.811	−.001	.810	−.003	.814	+.001
1888	.825	+.013	.809	−.004	.815	+.002
1889	.814	+.002	.809	−.004	.816	+.003
1890	.809	−.003	.808	−.005	.810	−.003
1891	.828	+.016	.826	+.013	.821	+.008
1892	.794	−.018	.800	−.013	.803	−.010
1893	.816	+.004	.824	+.011	.824	+.011
1894	.805	−.007	.814	+.001	.811	−.002
1895	.818	+.006	.821	+.008	.813	.000
1896	.814	+.002	.816	+.003	.820	+.007
Mean	29.812		29.813		29.813	

Table VI shows that in India the extreme amplitude of the pressure oscillation in the case of the crude means is 0.061, in the case of the means corrected for the 11-year cycle 0.045, and in the case of the means corrected for both cycles 0.031. This diminution in the amplitude of the oscillation with each successive correction, though not a proof of the correctness of these two cycles, is yet a substantial addition to the arguments in their favor. The concluding column of variations exhibits a marked excess of pressure in 1864 and 1865, and again in 1884 and 1885, but there is no similar excess shown in 1844 and 1845, so that as far as can be judged at present the variation is not one which can be anticipated each twenty years, but would appear on each occasion to have been due to local causes, as, for example, heavy snowfall in the Himalayas, etc. Beyond this single coincidence the variations give no indication of the march of any other cycle of change. The departures are small; they exhibit rapid changes of sign, and the only point about them worthy of note appears to be the general tendency to excess during the past thirty years, and a general tendency to deficiency in the first twenty years. In addition there is an instance of decided excess in the year 1877, but this excess, though, as a matter of fact, accompanied with very large meteorological variations in India, also appears to have been an isolated occurrence, probably also attributable to local causes. The year 1877 was a year of maximum positive variation in the 9-year cycle, and the normal excess of pressure was intensified by independent causes.

The investigation, so far as it has proceeded up to this point, shows that the series of combined pressure observations of the three stations, Bombay, Madras, and Calcutta, exhibits two cycles of change, viz, a cycle of eleven years (perhaps agreeing with the changes in the number of spots on the solar surface), and a variation agreeing with a 9-year period. These two sets of variations are shown in Table VII.

TABLE VII.—*Cycles of departures from normal barometric pressure.*

11-year cycle.		9-year cycle.	
	Inch.		*Inch.*
1st year	−.0015	1st year	+.008
2d year	+.0020	2d year	−.004
3d year	+.0009	3d year	−.006
4th year	+.0159	4th year	−.007
5th year	+.0050	5th year	−.002
6th year	+.0007	6th year	+.005
7th year	+.0023	7th year	−.003
8th year	−.0064	8th year	.000
9th year	−.0078	9th year	+.003
10th year	−.0094		
11th year	−.0027		

Finally it has been shown that when the above variations have been applied as corrections to the annual pressure values the amplitude of the pressure oscillation is very materially diminished, and that the residual variations exhibit no further sign of cyclical change during the period under discussion.

The next step in the investigation is to attempt to connect these periodic changes in pressure with the records of weather in India. In the Famine Commission Report, on page 34, there is given a table showing the rainfall at Madras for the years 1800 to 1878, and to this I have added the annual rainfall for the subsequent years up to 1896. The objections to the employment of the records of a single station for the purpose of showing the connection between pressure and rainfall are sufficiently obvious to every one. The following remarks by the late Mr. Pogson, C. I. E., government astronomer at Madras, may, however, be quoted to illustrate the difficulties which must be faced. The year 1877 over India generally was one of disastrously deficient rainfall, yet in Madras "in 1877 a purely cyclonic rainfall in May added 21 inches abnormally to the annual amount, and a similar quantity in November was also chiefly cyclonic. Deducting these amounts the register for the year would have been 24 instead of 66 inches." With this caution the process of connecting the march of the two elements will now be proceeded with. Table VIII gives the table of rainfall mentioned above. The first, fourth, and seventh columns give the years; the second, fifth, and eighth, Wolff's relative number of sun spots; and the third, sixth, and ninth, the annual rainfall at the Madras observatory. Attached to each figure giving the rainfall is a number (1 to 9) which shows the position of the year in the 9-year cycle.

TABLE VIII.—*Wolff's relative numbers for sun-spot frequency and the annual rainfall in inches and tenths at Madras Observatory.*

Year.	Sun-spot frequency.	Rainfall.	Year.	Sun-spot frequency.	Rainfall.	Year.	Sun-spot frequency.	Rainfall.
1800	15.3	? (5)	1833	8.5	37.1 (2)	1866	16.3	51.4 (8)
1801	24.0	? (6)	1834	13.2	39.0 (3)	1867	7.3	24.4 (9)
1802	55.0	? (7)	1835	56.9	41.5 (4)	1868	37.3	41.4 (1)
1803	71.2	66.1 (8)	1836	121.8	44.8 (5)	1869	73.9	32.3 (2)
1804	73.1	31.1 (9)	1837	138.3	49.3 (6)	1870	139.1	74.1 (3)
1805	47.6	31.2 (1)	1838	103.1	52.3 (7)	1871	111.2	56.4 (4)
1806	28.9	61.5 (2)	1839	85.8	53.1 (8)	1872	101.7	73.7 (5)
1807	9.4	14.3 (3)	1840	63.2	58.7 (9)	1873	66.3	51.8 (6)
1808	7.7	? (4)	1841	36.8	58.3 (1)	1874	44.6	62.9 (7)
1809	2.5	? (5)	1842	24.2	36.5 (2)	1875	17.1	37.1 (8)
1810	0.0	? (6)	1843	10.7	50.3 (3)	1876	11.3	21.6 (9)
1811	1.4	39.7 (7)	1844	15.0	65.4 (4)	1877	12.3	66.2 (1)
1812	5.5	? (8)	1845	40.1	38.1 (5)	1878	3.4	28.7 (2)
1813	12.8	45.1 (9)	1846	61.5	79.8 (6)	1879	6.0	54.3 (3)
1814	14.4	32.4 (1)	1847	98.4	81.0 (7)	1880	32.3	61.8 (4)
1815	35.4	56.0 (2)	1848	124.3	54.8 (8)	1881	54.2	44.0 (5)
1816	46.4	41.2 (3)	1849	95.9	39.8 (9)	1882	59.3	50.2 (6)
1817	41.5	63.6 (4)	1850	66.5	36.9 (1)	1883	62.8	60.5 (7)
1818	30.0	76.3 (5)	1851	64.5	64.3 (2)	1884	63.3	78.9 (8)
1819	24.2	36.3 (6)	1852	54.2	72.7 (3)	1885	50.3	47.9 (9)
1820	15.0	70.0 (7)	1853	39.0	35.8 (4)	1886	25.7	47.8 (1)
1821	6.1	47.1 (8)	1854	20.6	43.2 (5)	1887	13.1	70.2 (2)
1822	4.0	59.6 (9)	1855	6.7	32.3 (6)	1888	6.7	62.5 (3)
1823	1.8	26.6 (1)	1856	4.3	47.0 (7)	1889	5.8	43.4 (4)
1824	8.6	33.7 (2)	1857	22.8	53.0 (8)	1890	7.1	28.0 (5)
1825	15.6	56.1 (3)	1858	54.8	48.5 (9)	1891	35.6	30.4 (6)
1826	30.0	60.7 (4)	1859	93.8	55.1 (1)	1892	73.8	42.0 (7)
1827	49.4	68.4 (5)	1860	95.7	27.6 (2)	1893	?	44.0 (8)
1828	62.5	37.9 (6)	1861	77.2	37.2 (3)	1894	?	47.8 (9)
1829	67.8	36.9 (7)	1862	59.1	38.2 (4)	1895	?	47.4 (1)
1830	70.7	32.4 (8)	1863	44.0	54.6 (5)	1896	?	68.7 (2)
1831	47.8	44.4 (9)	1864	46.9	47.2 (6)			
1832	27.5	18.5 (1)	1865	30.5	41.6 (7)			

Taking first the 11-year cycle, the above table shows a general direct agreement between the number of solar spots and the amount of rainfall at Madras. In order to obtain values which can be compared directly with the pressure values of the 11-year cycle given in Table III, the annual rainfall values for each eleven years, beginning with 1808, have been combined, as shown in Table IX.

TABLE IX.—*Annual rainfall at Madras, arranged in 11-year cycles.*

Year.	Rainfall.	Year.	Rainfall.	Year.	Rainfall.	Year.	Rainfall.	Year.	Rainfall.	Year.	Rainfall.	Year.	Rainfall.	Year.	Rainfall.	Year.	Rainfall.	Year.	Rainfall.	Mean rainfall.	Variation from the mean of all cycles.
1808	?	1819	36.3	1830	32.4	1841	58.3	1852	72.7	1863	54.6	1874	62.9	1885	47.9	1896	68.7	54.2	+ 5.4
1809	?	1820	70.0	1831	44.4	1842	36.5	1853	35.8	1864	47.2	1875	37.1	1886	47.8	....	....	45.5	— 3.3
1810	?	1821	47.1	1832	18.5	1843	50.3	1854	43.2	1865	41.6	1876	21.6	1887	70.2	....	....	41.8	— 7.0
1811	39.7	1822	59.6	1833	37.1	1844	65.4	1855	32.3	1866	51.4	1877	66.2	1888	62.5	....	....	51.8	+ 3.0
1812	?	1823	26.6	1834	39.0	1845	38.1	1856	47.0	1867	24.4	1878	28.7	1889	43.4	....	....	35.3	—13.5
1813	45.1	1824	33.7	1835	41.5	1846	79.8	1857	58.0	1868	41.4	1879	54.3	1890	28.0	....	....	47.1	+ 1.7
1814	32.4	1825	56.1	1836	44.8	1847	81.0	1858	48.5	1869	32.3	1880	61.8	1891	30.4	....	....	48.4	— 0.4
1815	56.0	1826	60.7	1837	49.3	1848	54.8	1859	55.1	1870	74.1	1881	44.0	1892	42.0	....	....	54.5	+ 5.7
1816	41.2	1827	38.4	1838	52.3	1849	39.8	1860	27.6	1871	56.4	1882	50.2	1893	44.0	....	....	50.0	+ 1.2
1817	63.6	1828	37.9	1839	53.1	1850	36.9	1861	37.2	1872	73.7	1883	60.5	1894	47.8	....	....	51.3	+ 2.5
1818	76.3	1829	36.9	1840	58.7	1851	64.3	1862	38.2	1873	51.8	1884	78.9	1895	47.4	....	....	56.6	+ 7.8

From Tables III and IX the following mean results have been obtained for Madras:

TABLE X.

Calendar years.		Cycle year.	Variations.	
Madras rainfall.	Indian pressure.		Rainfall.	Pressure.
			Inches.	*Inch.*
1808-96	1841-96	First	+ 5.4	—.0015
1809-86	1842-86	Second	— 3.3	+.0030
1810-87	1843-87	Third	— 7.0	+.0009
1811-88	1844-88	Fourth	+ 3.0	+.0159
1812-89	1845-89	Fifth	—13.5	+.0005
1813-90	1846-90	Sixth	— 1.7	+.0007
1814-91	1847-91	Seventh	— 0.4	+.0023
1815-92	1848-92	Eighth	+ 5.7	—.0064
1816-93	1849-93	Ninth	+ 1.2	—.0078
1817-94	1850-94	Tenth	+ 2.5	—.0094
1818-95	1851-95	Eleventh...	+ 7.8	—.0027

This is not a very close agreement, but, as will be seen from the following diagram, Fig. 3, there does exist a rough agreement between the variations of pressure and the variations of rainfall:

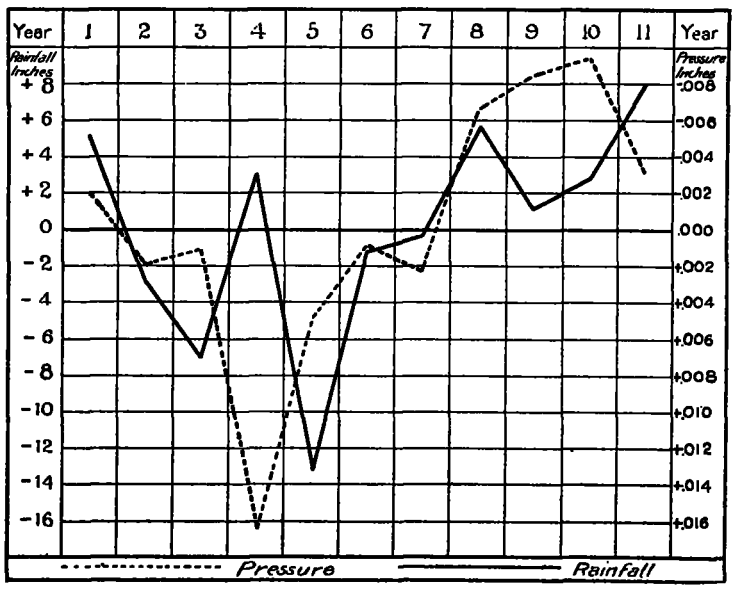

Fig. 3.—Indian pressure and Madras rainfall, 11-year cycle.

Turning next to the 9-year cycle, and treating the Madras rainfall in the same manner, only dividing it into 9-year instead of 11-year periods, the following, Table XI, is constructed:

TABLE XI.

Year.	Rainfall.	Year.	Rainfall.	Year.	Rainfall.	Year.	Rainfall.	Year.	Rainfall.	Year.	Rainfall.	Year.	Rainfall.	Year.	Rainfall.
	Inches		*Inches*		*Inches*		*Inches*		*Inches*		*Inches*		*Inches*		*Inches*
1805...	31.2	1814...	32.4	1823...	26.6	1832...	18.5	1841...	58.3	1850..	36.9				
1806...	61.5	1815...	56.0	1824...	33.7	1833...	37.1	1842...	36.5	1851..	64.3				
1807...	14.3	1816...	41.2	1825...	56.1	1834...	39.0	1843...	50.3	1852..	72.7				
1808...	?	1817...	63.6	1826...	60.7	1835...	41.5	1844...	65.4	1853..	35.8				
1809...	?	1818...	76.3	1827...	33.4	1836...	44.8	1845...	38.1	1854..	43.2				
1810...	?	1819...	36.3	1828...	37.9	1837...	49.3	1846...	79.8	1855..	32.3				
1811...	39.7	1820...	70.0	1829...	36.9	1838...	52.3	1847...	81.0	1856..	47.0				
1812...	?	1821...	47.1	1830...	32.4	1839...	53.1	1848...	54.8	1857..	53.0				
1813...	45.1	1822...	59.6	1831...	44.4	1840...	58.7	1849...	39.8	1858..	48.5				

Year.	Rainfall.	Year.	Rainfall.	Year.	Rainfall.	Year.	Rainfall.	Year.	Rainfall.	Mean.	Variation from mean of all cycles.
	Inches		*Inches*		*Inches*		*Inches*		*Inches*	*Inches*	*Inches*
1859...	55.1	1868..	41.4	1877..	66.2	1886..	47.8	1895..	47.4	42.0	—6.8
1860...	27.6	1869..	32.3	1878..	28.7	1887..	70.2	1896..	68.7	47.0	—1.8
1861...	37.2	1870..	74.1	1879..	54.3	1888..	62.5	.....	.....	50.2	+1.4
1862...	38.2	1871..	56.4	1880..	61.8	1889..	43.4	.....	.....	51.9	+3.1
1863...	54.6	1872..	73.7	1881..	44.0	1890..	28.0	.....	.....	54.6	+5.8
1864...	47.2	1873..	51.8	1882..	50.2	1891..	30.4	.....	.....	46.1	—2.7
1865...	41.6	1874..	62.9	1883..	60.5	1892..	42.0	.....	.....	53.4	+4.6
1866...	51.4	1875..	37.1	1884..	78.9	1893..	44.0	.....	.....	50.2	+1.4
1867...	24.4	1876:	21.6	1885..	47.9	1894..	47.8	.....	.....	43.8	—5.0

From Tables V and XI the following results are obtained:

TABLE XII.

Calendar years.		Cycle year.	Variations.	
Madras rainfall.	Indian pressure.		Rainfall.	Pressure.
			Inches.	*Inch.*
1805-95	1841-95	First	—6.8	+.008
1806-96	1842-96	Second	—1.8	—.004
1807-88	1843-88	Third	+1.4	—.006
1808-89	1844-89	Fourth	+3.1	—.007
1809-90	1845-90	Fifth	+5.8	—.002
1810-91	1846-91	Sixth	—2.7	+.005
1811-92	1847-92	Seventh....	+4.6	—.003
1812-93	1848-93	Eighth	+1.4	.000
1813-94	1849-94	Ninth	—5.0	+.003

This table gives the following diagram:

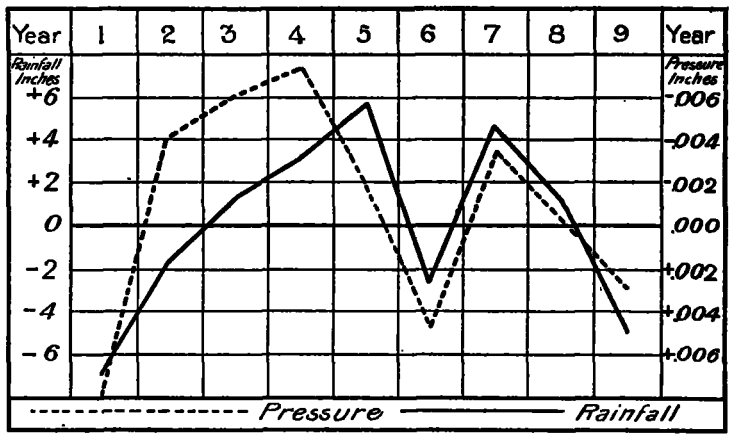

FIG. 4.—Indian pressure and Madras rainfall, 9-year cycle.

The above curves show that in the barometric pressure over India and in the rainfall at Madras there exists an 11-year cycle presumably agreeing with the relative frequency of solar spots, and in addition a 9-year cycle in which the agreement between pressure and rainfall is even more marked and more distinct than in the case of the 11-year cycle.

For the reasons stated above the rainfall discussion has been hitherto confined to the records of Madras observatory,

the rainfall records of the whole of India being available for only a relatively short period. From 1864 onward, however, rainfall returns are obtainable for the whole country, and these returns have been utilized to construct Table XIII.

TABLE XIII.—*Variations of rainfall for all India arranged in 11-year cycles.*

Year.	Variation.	Year.	Variation.	Year.	Variation.	Year.	Variation.	Mean variation.
	Inches.		Inches.		Inches.		Inches.	Inches.
1863	.....	1874	+ 4.6	1885	+ 1.1	1896	— 4.8	+ 0.3
1864	— 5.5	1875	+ 2.4	1886	+ 3.0	.....	.....	0.0
1865	— 0.8	1876	— 4.5	1887	+ 2.6	.....	.....	— 0.9
1866	— 2.1	1877	— 4.3	1888	— 1.5	.....	.....	— 2.6
1867	+ 2.8	1878	+ 6.3	1889	+ 2.5	.....	.....	+ 3.8
1868	— 6.6	1879	+ 1.7	1890	+ 0.7	.....	.....	— 1.4
1869	+ 0.4	1880	— 1.6	1891	— 3.5	.....	.....	— 1.6
1870	+ 1.5	1881	+ 0.1	1892	+ 5.1	.....	.....	+ 2.2
1871	+ 0.9	1882	+ 2.6	1893	+ 9.1	.....	.....	+ 4.2
1872	+ 2.3	1883	— 0.1	1894	+ 6.5	.....	.....	+ 2.9
1873	— 4.5	1884	+ 1.7	1895	— 2.9	.....	.....	— 1.9

The 11-year cycle of Indian pressure (Table III or VII) and of rainfall for all India (Table XIII) are shown in Fig. 5.

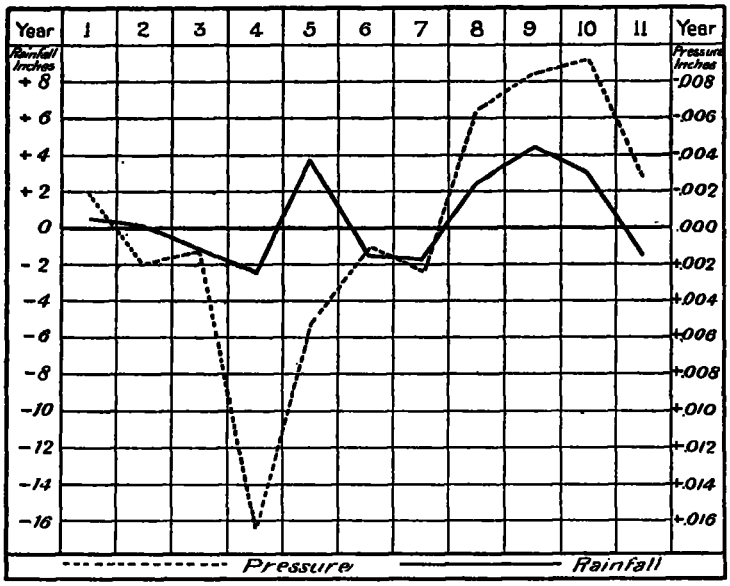

FIG. 5.—Indian pressure and rainfall for all India, 11-year cycle.

The amplitude of the rainfall oscillation for the whole of India is only one-third of that for Madras, but the shape of the curve is the same, and the general agreement between the rainfall and pressure variations is unmistakable.

Dealing next with the same figures, but distributing them over a 9-year cycle, there results Table XIV, as follows:

TABLE XIV.—*Variations of rainfall for all India arranged in 9-year cycles.*

Year.	Variation.	Year.	Variation.	Year.	Variation.	Year.	Variation.	Year.	Variation.	Mean variation.
	Inches.		Inches.		Inches.		Inches.		Inches.	Inches
.....	.....	1868	—6.6	1877	—4.3	1886	+3.0	1895	—2.9	—2.7
... .	.....	1869	+0.4	1878	+6.3	1887	+2.6	1896	—4.8	+1.1
.....	.....	1870	+1.5	1879	+1.7	1888	—1.5	.....	.....	+0.6
.....	.....	1871	+0.9	1880	—1.6	1889	+2.5	.....	.....	+0.6
.....	.....	1872	+2.3	1881	+0.1	1890	+0.7	.....	.....	+1.0
1864...	—5.5	1873	—4.5	1882	+2.6	1891	—3.5	.....	.....	—2.7
1865....	—0.8	1874	+4.6	1883	—0.1	1892	+5.1	.....	.....	+2.2
1866....	—2.1	1875	+2.4	1884	+1.7	1893	+9.1	.....	.....	+2.8
1867....	+2.8	1876	—4.5	1885	+1.1	1894	+6.5	.....	.....	+1.5

whence, with Table V or VII, the accompanying curves of Fig. 6 are obtained:

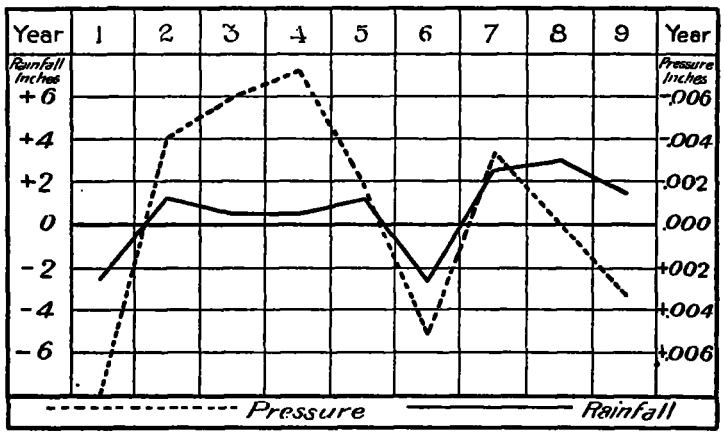

FIG. 6.—Indian pressure and rainfall for all India, 9-year cycle.

It would appear, then, from this investigation, that there are two cycles, both traceable in pressure and rainfall, affecting the weather over the Indian region, the one running through a period of eleven years and the other through a period of nine years. Both appear to be more distinctly traceable in the records of southern India (Madras) than in the records of the whole of India. That these two cycles of change will not account for all the variations of rainfall is sufficiently apparent from the records of the years 1877, 1881, 1887, 1890, 1892, and 1893 in the case of Madras, and 1876, 1883, 1886, 1887, and 1896 in the case of India, as a whole, but they may assist in explaining the numerous variations which are on record, and may afford help in determining the general characteristics of future seasons.

In order to test the practical utility of the system the cyclical variations of rainfall for Madras and for India, for each year from 1864 to 1896, were calculated according to this method, and in the following table are given side by side with the actual variations observed in these years.

TABLE XV.—*Cyclical variations of annual rainfall.*

Year.	Madras.				Whole of India.			
	11-year cycle.	9-year cycle.	Total computed.	Actual observed.	11-year cycle.	9-year cycle.	Total computed.	Actual observed.
	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.
1864	— 3.3	— 2.7	— 6.0	— 2.8	0.0	— 2.7	— 2.7	— 5.5
1865	— 7.0	+ 4.6	— 2.4	— 8.4	— 0.9	+ 2.2	+ 1.3	— 0.8
1866	+ 3.0	+ 1.4	+ 4.4	+ 1.4	— 2.6	+ 2.8	+ 0.2	— 2.1
1867	—13.5	— 5.0	—18.5	—25.6	+ 3.8	+ 1.5	+ 5.3	+ 2.8
1868	— 1.7	— 6.8	— 8.5	— 8.6	— 1.4	— 2.7	— 4.1	— 6.6
1869	— 0.4	— 1.8	— 2.2	—17.7	— 1.6	+ 1.1	— 0.5	+ 0.4
1870	+ 5.7	+ 1.4	+ 7.1	+24.1	+ 2.2	+ 0.6	+ 2.8	+ 1.5
1871	+ 1.2	+ 3.1	+ 4.3	+ 6.4	+ 4.2	+ 0.6	+ 5.2	+ 0.9
1872	+ 2.5	+ 5.8	+ 8.3	+23.7	+ 2.9	+ 1.0	+ 3.9	+ 2.3
1873	+ 7.8	— 2.7	+ 5.1	+ 1.8	— 1.9	— 2.7	— 4.6	— 4.5
1874	+ 5.4	+ 4.6	+10.0	+12.9	+ 0.3	+ 2.2	+ 2.5	+ 4.6
1875	— 3.3	+ 1.4	— 1.9	—12.9	0.0	+ 2.8	+ 2.8	+ 2.4
1876	— 7.0	— 5.0	—12.0	—28.4	— 0.9	+ 1.5	+ 0.6	— 4.5
1877	+ 3.0	— 6.8	— 3.8	+16.2	— 2.6	— 2.7	— 5.3	— 4.3
1878	—13.5	— 1.8	—15.3	—22.3	+ 3.8	+ 1.1	+ 4.9	+ 6.3
1879	— 1.7	+ 1.4	— 0.3	+ 4.3	— 1.4	+ 0.6	— 0.8	+ 1.7
1880	— 0.4	+ 3.1	+ 2.7	+11.8	— 1.6	+ 0.6	— 1.0	— 1.6
1881	+ 5.7	+ 5.8	+11.5	— 6.0	+ 2.2	+ 1.0	+ 3.2	+ 0.1
1882	+ 1.2	— 2.7	— 1.5	+ 0.2	+ 4.2	— 2.7	+ 1.5	+ 2.6
1883	+ 2.5	+ 4.6	+ 7.1	+10.5	+ 2.9	+ 2.2	+ 5.1	— 0.1
1884	+ 7.8	+ 1.4	+ 9.2	+28.9	— 1.9	+ 2.8	+ 0.9	+ 1.7
1885	+ 5.4	— 5.0	+ 0.4	— 2.1	+ 0.3	+ 1.5	+ 1.8	+ 1.1
1886	— 3.3	— 6.8	—10.1	— 2.2	0.0	— 2.7	— 2.7	+ 3.0
1887	— 7.0	— 1.8	— 8.8	+20.2	— 0.9	+ 1.1	+ 0.2	+ 2.6
1888	+ 3.0	+ 1.4	+ 4.4	+12.5	— 2.6	+ 0.6	— 2.0	— 1.5
1889	—13.5	+ 3.1	—10.4	— 6.6	+ 3.8	+ 0.6	+ 4.4	+ 2.5
1890	— 1.7	+ 5.8	+ 4.1	—22.2	— 1.4	+ 1.0	— 0.4	+ 0.7
1891	— 0.4	— 2.7	— 3.1	—19.6	— 1.6	— 2.7	— 4.3	— 3.5
1892	+ 5.7	+ 4.6	+10.3	— 8.0	+ 2.2	+ 2.2	+ 4.4	+ 5.1
1893	+ 1.2	+ 1.4	+ 2.6	— 6.0	+ 4.2	+ 2.8	+ 7.0	+ 9.1
1894	+ 2.5	— 5.0	— 2.5	— 2.2	+ 2.9	+ 1.5	+ 4.4	+ 6.5
1895	+ 7.8	— 6.8	— 1.0	— 2.6	— 1.9	— 2.7	— 4.6	— 2.9
1896	+ 5.4	— 1.8	+ 3.6	+18.7	+ 0.3	+ 1.1	+ 1.4	— 4.8

That the method of the two cycles would have given approximately correct rainfall variations in the majority of years is obvious, and that the calculated variations (more particularly in the case of Madras alone) should be smaller than the actual variations is not surprising, but the actual and calculated values in some years are so very divergent that it must be reluctantly conceded that it is impossible by this method "to determine beforehand with any certainty the probable amount of rain in any season, such as would admit of timely precautions being taken against impending drought."

[NOTE.—In publishing this important paper by Mr. Dallas promptly, without incurring the great delay that would be necessitated by submitting the proof sheets to him, several matters have been noticed by the Editor which, although unimportant to the general trend of the argument, may possibly be worth repeating as helpful to the reader.

The word "variations" is used by Mr. Dallas always in the same sense as the word "departures" is used by other writers, viz, the observed value minus the computed value, so that a plus variation is also a plus departure.

The adoption of a regular 11-year cycle, instead of the somewhat irregular sun-spot numbers, which are given in Table VIII (inasmuch as the 11-year and the sun-spot cycles depart widely from each other), seems to show that the 11-year period has no direct connection with the sun spots, and it should, therefore, not be spoken of as a sun-spot period, but simply an 11-year cycle.

The pressures given in Table I for three different series of years should, strictly speaking, be reduced to a common system by adopting the years 1853–1896 as the basis. The mean pressures for these forty-four years are: Madras, 29.844; Bombay, 29.813; Calcutta, 29.784; the mean of all three is 29.814. Adopting this latter figure as the base, we reduce each of the three stations to a common standard by applying the corrections, —0.030, + 0.001, + 0.030. Fortunately these corrections are the same as those used by the author in preparing Table IV and Fig. 1.

With regard to the annual pressures for Mauritius, Mr. Dallas states that they were corrected for the 11-year cycle in order to obtain the curve of Fig. 2. We infer that the corrections were specially computed by him from the Mauritius observations, and that he does not mean to say that he corrected the latter by using the means for India given in Table III.

No reason is given for omitting from Tables IX and XI the earliest years, as given in Table VIII.

In Tables X and XII the author has compared together the Madras rainfall and the Indian pressure, but for quite different groups of years. If the comparison had been for a uniform system of stations and of years, the results might have been more harmonious. It is difficult to separate the influence of this discrepancy as to locality and time from the influence of the general want of physical connection between the rainfall and the pressure.

In Tables XIII, XIV, and XV the figures given in the manuscript for the variations of rainfall for all India show some slight discrepancies, viz: XIII, 1886, +3.0; 1887, +2.4; 1889, +2.5; XIV, 1886, +3.2; 1887, +2.4; 1889, +2.4; XV, 1886, +3.2; 1887, +2.6; 1889, +2.4. These discrepancies the Editor has removed, so that the three tables may be harmonious.

With regard to the variations of rainfall at Madras, as given in Table XV, the reader will notice that the figures of column 5 may be reproduced by assuming the normal for Madras at 50.0 inches and computing from this the departures of the individual years given in Table VIII. Two small discrepancies will be found, viz, the variation for 1878 should be —21.3, and for 1890, —22.0, instead of —22.3 and —22.2, respectively, as published in Table XV.—ED.]

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MEXICAN CLIMATOLOGICAL DATA.

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